# High Energy, Long Cycle Life, and Extreme Temperature Lithium-Sulfur Battery for Venus Missions

Completed Technology Project (2017 - 2020)

## Project Introduction

Most space missions utilize some form of energy storage, such as a battery on their spacecraft. The need for long cycle life, high energy density batteries with minimal self-discharge and enhanced safety are the most critical requirements of energy storage systems used in extended duration space missions. Venus presents the most significant challenge to energy storage systems due to a combination of high temperature (452°C) and presence of corrosive gases ($CO_2$, CO, $SO_2$, and $N_2$). While the rechargeable high temperature sodium sulfur batteries have been previously operated on space-shuttle flights, concerns with their safety due to the highly reactive sodium metal, limited energy density (theoretical = 760 Wh kg-1), corrosive discharge products at 100% depth of discharge, and use of solid electrolyte with poor mechanical strengths and ionic conductivities (e.g. beta-alumina) pose limitations for their use in extended duration space missions such as to Venus. In contrast, the lithium sulfur battery has higher energy density (theoretical = 2735 Wh kg-1), is safer due to the higher ionization energy of lithium vs. sodium, and its discharge product, $Li_2S$, is not corrosive. This proposed research will explore the combined capabilities of high energy density lithium sulfur batteries incorporating solid-state, high-temperature stable, superionic ($Li^+$ only) electrolytes, including phosphates, garnet-type metal-oxide ceramics, and sulfides, that can enable operation of high energy and power densities, high cycle-life, low self-discharge and high safety, rechargeable molten lithium sulfur batteries in Venus-like conditions. Technically, the specific aims of this proposed research include (i) the design of stable interfaces between the solid electrolytes and the molten lithium and sulfur electrodes, (ii) a novel scheme to construct porous ceramic solid electrolyte hosts to encapsulate active cathode materials, and (iii) hollow lithiated silicon anodes to restrict the fracture of solid electrolytes by confining electrode volume changes, and (iv) construction of a high energy, long cycle life, safe and durable lithium sulfur battery incorporating the above improved components operable at temperatures 200-500°C. These aims will map the parameter space for electrochemical performance, high temperature stability, interfacial properties, and mechanisms for cell degradation of the proposed lithium sulfur batteries. The success of high temperature, safe, and long cycle life lithium sulfur batteries will enable a sustainable energy source to propel not only future NASA space missions in extreme environments but also terrestrial applications such as grid energy storage and downhole explorations in the oil and gas industry where temperatures exceed 200°C.

Image Not Available

High Energy, Long Cycle Life, and Extreme Temperature Lithium-Sulfur Battery for Venus Missions

## Table of Contents



## Organizational Responsibility

**Responsible Mission Directorate:**

Science Mission Directorate (SMD)

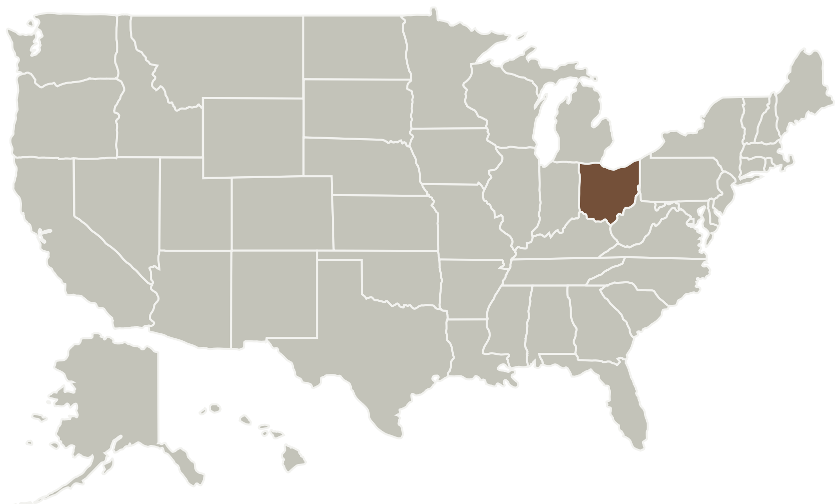
**Lead Organization:**

University of Dayton

**Responsible Program:**

Hot Operating Temperature Technology

**Primary U.S. Work Locations and Key Partners**



| Organizations Performing Work | Role | Type | Location |
|---|---|---|---|
| University of Dayton | Lead Organization | Academia | Dayton, Ohio |
| University of Akron Main Campus | Supporting Organization | Academia | Akron, Ohio |
| University of Dayton Research Institute | Supporting Organization | Academia | Dayton, Ohio |

| Primary U.S. Work Locations |
|---|
| Ohio |

## Project Management

**Program Director:**

Carolyn R Mercer

**Program Manager:**

Quang-viet Nguyen

**Principal Investigator:**

Jitendra Kumar

**Co-Investigators:**

Priyanka Bhattacharya
Yu Zhu
Claudette M Groeber
Guru Subramanyam

## Technology Areas

**Primary:**

- TX03 Aerospace Power and Energy Storage
  - └ TX03.2 Energy Storage
    - └ TX03.2.1 Electrochemical: Batteries

## Target Destination

Others Inside the Solar System